Geospatial Digital Rights Management in Geovisualizations

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ABSTRACT: Geovisualization offers powerful tools, techniques, and strategies to present, explore, analyze, and manage geoinformation. Interactive geovirtual environments such as virtual 3D maps or virtual 3D city models, however, raise the question how to control geodata usage and distribution. We present a concept for embedding digital rights in geovisualizations. It is based on geo-documents, an object-oriented scheme to specify a wide range of geovisualizations. Geo-documents are assembled by building blocks categorized into presentation, structure, interaction, animation, and Digital Rights Management (DRM) classes. DRM objects allow for defining permissions and constraints for all objects contained in geo-documents. In this way, authors of geovisualizations can control how their geo-documents are used, personalized, and redistributed by users. The strengths of the presented concept include the ability to integrate heterogeneous 2D and 3D geodata within a compact design scheme and the ability to cope with privacy, security, and copyright issues. Embedded digital rights in geovisualizations can be applied to improve the usability of geodata user interfaces, to implement publisher-subscriber communication systems for geodata, and to establish business models for geodata trading systems.

KEYWORDS: Geospatial DRM, Digital Rights Management, Geovisualization, Geovirtual Environments.

1 Introduction

As geovisualizations become part of an increasing number of products and systems operating on geoinformation, approaches to systematically assemble, protect, and control embedded geoinformation gain attention. As long as geoinformation is acquired and used within a trusted and known context, protection and controlling issues can be resolved in informal ways. Once products and systems are targeted at an open context, such as in the case of consumer products, these issues appear to be critical due to technical, legal, and strategic challenges – a systematic and reliable solution is required.

DRM is concerned with models of dissemination and use of intellectual property assets. Due to its impact on industry and business models DRM technology is receiving more and more attention; its main objective is to define techniques and mechanisms to identify, describe, package, distribute, and control usage of digital contents. In many areas, first of all the film industry, a lot of DRM technology is emerging. With respect to geodata the Open Geospatial Consortium (OCG, 2004) has recently pointed out that the “lack of a geospatial Digital Rights Management (GeoDRM) capability is a major barrier to broader adoption of Web based geospatial technologies”. Consequently, DRM approaches specific to the nature and usage of geoinformation need to be identified.

We present a concept for a GeoDRM technology based on embedding digital rights in geovisualizations. The concept offers a generic solution for assembling, protecting, and controlling geoinformation contents as part of geovisualizations. It is intended for those applications and systems that deploy geovisualization as an important part of their interface between user and geoinformation. As core concept, we introduce *geo-documents*, which form a framework for interactively visualizing geodata with *built-in digital rights* and support effective communicate of geoinformation for specific users and tasks by software products. Although we focus on 3D geovisualizations, the concept can be transferred and applies to 2D geovisualizations as well.

1.1 Geovisualization-Based Systems

Geovisualization plays an important role in software systems that contain geodata as dominant category of objects to be displayed, manipulated, and managed. Examples of these *geovisualization-based systems* represent interactive atlases, environmental and urban monitoring systems, radio-network planning systems, traffic control systems, and tourist information systems. From a software engineering’s point of view, geovisualizations can be regarded as a kind of user interface technology. That is, interactive geovisualizations represent a central component in system design and implementation – they are responsible for the communication between users and geoinformation.

As a common characteristic, geovisualization-based systems are located towards the end of the economic value-added chain of geoinformation. The major part of research in geoscience, of course, is focused on underlying technology for this chain, for instance geodata acquisition, processing, web-based delivery, and standardizations. However, fewer concepts are known for the systematic assembly of geodata and associated usage rights and constraints.

To actually develop a geovisualization-based system, a number of steps and conditions must be satisfied:
- *Acquiring Geodata.* Appropriate geodata must be identified and acquired. Required geodata must be available in terms of quantity and quality to the degree the application demands. Geodata must also be cost-effective in terms of pricing and licensing;
- *Integrating Geodata.* Geodata of different types, formats, and sources must be integrated into a framework for visualization;
- *Encoding Geodata.* Geodata must be transformed such that it can be used and processed by the geovisualization-based system. For this, efficient encodings must be applied, for example, to fulfill requirements of real-time graphics;
- *Digital Rights Management.* DRM techniques are required to cope with copyright, data security, and privacy issues.

1.2 Embedding Geodata into Applications

Geodata must be integrated at the application level, that is, the collection of geodata of an application has to be combined and embedded into the application as its primary contents. There are several ways for implementing this task:
- *Integration at File System Level:* Geodata are managed as raw data stored in the file system. This represents the most primitive form of geodata integration, both simple in its implementation and efficient. However, for each type of geodata and for each data format, specialized import functionality has to be implemented;
- *Integration at Database Level:* Geodata are structured and managed by relational or object-based database systems. In particular, this method is used if geodata has to be maintained by the application, and if large amounts of data are to be managed. This method requires that common schemata are defined that encompass the formats and types of geodata used by the application;
- *Integration at Service Level:* Geodata are accessed using services that retrieve, combine and manage geodata available by the service provider's site. This method completely abstracts from the physical representation of geodata by providing an abstract functional access to geodata. In particular, this approach becomes more and more attractive due to standardized service definitions as those defined by the Open Geospatial Consortium, Inc. (OGC);
- *Integration at Visualization Level:* Geodata are accessed through the graphical representation and manipulated through interactive user interfaces. In a sense, this method is the most abstract form of integration. It does not assume a specific physical representation or functional interface, but requires that geodata can be transformed into primitives used in the visualization process. An approach for an object-oriented coupling of GIS and visualization system is described in Döllner and Hinrichs (1999).

The first three integration strategies operate on the data level, that is, they integrate actual geodata. We can apply standards such as object definitions, service definitions, and format definitions provided by OpenGIS and general data description languages such as XML and its derivatives such as the Geography Markup Language GML and the Scalable Vector Graphics language SVG. They are well suited for specifying, integrating, storing, and distributing geodata, and they establish a basis for interoperability of geodata services.

The last integration strategy, located at the visualization level, offers a large, still unexploited potential, in particular for commercial applications and consumer products based on geodata. If geodata is embedded in those applications, there is an inherent need for defining rights and constraints on geodata, its usage and distribution. There is, of course, less demand for an open application architecture or interoperability since these applications represent end-consumer products in general. The concept for embedding geodata at the visualization level must be both *efficient* in terms of interactive rendering performance and storage requirements as well as *flexible* in terms of configuration and adaptation to individual software products.

1.3 Usage Rights & Constraints in Geovisualizations

The need for usage rights and constraints results from the inherent flexibility of interactive geovisualizations. In general, a large bandwidth of uses is possible because not only an author but also a user can configure and actively define the various steps in the visualization pipeline. The visualization pipeline (Fig. 1), both a theoretical and practical model underlying most visualization systems, identifies three main stages, the filtering stage (data selection), the representation stage (data encoding and transformation), and the presentation stage (data rendering and display); for a general introduction see Spence, 2001.

In contrast to traditional, static media, interactive geovisualizations need to control these stages, that is, they require means by which the author can control the degrees of freedom within an interactive geovisualization environment. In our concept, we specify these digital rights by explicit constraints and rights as a specialized category of building blocks of geovisualizations. Thereby, the author can configure the degree of reusability and "openness" for each individual component of geovisualizations. Through this, the author can control usage, distribution, and personalization of geo-documents. In a sense, geo-documents act as intelligent geodata containers with built-in digital rights.

2 Concepts of Geo-Documents

We introduce concepts of *geo-documents* as a framework for representing geodata by means of virtual 3D geo environments such as virtual 2D and 3D maps, virtual 3D city models, and virtual 3D landscape models.

2.l Geo-Document Classes

Geo-document classes define components of which geo-documents can be built at a high level of abstraction compared to computer graphics systems or geoinformation systems. The classes aim at supporting presentation, interaction, animation, and editing of 2D and 3D geodata, and they tend to be "orthogonal" to each other, that is, they specify complementary aspects and can be combined in almost arbitrary fashion to build complex geovirtual environments.

To create an individual geo-document, instances of geo-document classes are created, assembled, and associated. Note that the term 'class' is used in the sense of object-oriented software modeling, that is, by class we mean "[…] a description of a set of objects that share the same attributes, operations, methods, relationships, and semantics." (OMG, 2003)

The collection of geo-document classes in our approach can be subdivided into five main categories:

- *Presentation Classes*: They define the visual representation of geodata such as terrain models, 3D city models, 2D raster data, 2D vector data, 2D symbols, and labels. Large-scale terrain models and large-scale terrain textures are represented as multiresolution models used to achieve real-time rendering;
- *Structure Classes*: They structure collections of objects within a single geo-document. In particular, they provide folders to hierarchically arrange objects, and categories to attribute additional semantics to objects. They are intended to manage large collections of geo-document objects in a user-specific or application-specific way;
- *Interaction Classes*: They define how users can interact with the geovirtual environment and its objects. We distinguish between navigation components such as virtual trackballs, virtual pedestrian navigation, or flight navigation, and action objects that define how objects react to events such as calling application-specific routines or executing hyperlinks;
- *Animation Classes*: They define time-dependent and event-dependent behavior of presentation objects. They are used to visualize time-dependent geodata as well as for producing animations. For instance, a visual bookmark object is used to record camera settings; it can perform a camera animation to fly to the recorded position at a later point in time;
- *Digital Rights Classes*: They define usage rights and constraints for presentation, structure, interaction, animation, and digital rights objects contained in geo-documents.

Detailed technical information on presentation, structure, interaction, and animation classes can be found in Döllner and Kersting (2000), who describe an implementation model of these classes.

To manually create a geo-document, authoring systems provide tools to create and manage geo-documents. A geo-document corresponds to a single document edited by the author, interactively constructed by instantiating geo-document objects. The LandXplorer system (3D Geo, 2004), for instance, represents an interactive authoring system closely related to the concepts presented.

To automatically create geo-documents, they may also be specified in an XML–based description. These XML specifications are processed by a geo-document engine, which constructs and assembles the corresponding objects on the server's side according to the XML description and stores or delivers the resulting geo-document for later use.

2.2 Examples of Geo-Documents

As a first example, consider a simple *3D map*. In this case, the geo-document consists of the digital terrain model and a set of terrain textures, each of which represents 2D raster data or 2D vector data, respectively. Each terrain texture can be regarded as an information layer, and it can be enabled or disabled independently. This way, different information layers can be visually combined in a single view based on image operators that define how terrain textures are combined.

A *3D city model* can be built in a similar way: A digital terrain model is combined with an aerial photography, represented as terrain texture. A 2D vector data set represents 2D ground plans of buildings together with an associated height value per building. 3D buildings, represented as geo-referenced 3D geo-document objects, result from extruding the vector data set of ground plans. Fig. 2 shows part of the user interface of an authoring system for geo-documents. It allows for interactively creating and composing geo-document objects.

3. Encoding of Geo-Documents

To encode geo-documents at the technical level, we take advantage of their object-oriented design. We have to concentrate on an efficient internal representation used for real-time rendering as well as on flexible mechanisms to embed the digital rights.

3.1 Graphics Representations

An important purpose of geo-documents is to serve for interactive visualization. For this, presentation objects need to be optimized with respect to real-time rendering. Therefore, we transform geodata of a geo-document into a representation suitable for real-time rendering, and we extract only those contents we actually need for interactive visualization.

In real-time computer graphics, there is a growing number of efficient algorithms for encoding and rendering of 3D graphics data. Most important work includes multiresolution models for terrain surfaces (e.g., progressive meshes, grid-based meshes), level-of-detail management of texture data (e.g., mip-mapping, clip-mapping), and optimization techniques for complex 3D scenes (e.g., view-frustum culling, occlusion culling, impostors). For details, see Akenine-Möller and Haines (2002), they give a general introduction of real-time graphics.

In most end-consumer products the graphics representation is sufficient since the original data is not explicitly required except in its visualized form or as subject of visual exploration or analysis. This justifies an internal representation different from the representation of the original data; we only provide the original geodata in addition if it is actually needed, for example, if geodata should be edited and exported by the application.

3.2 Object-Oriented Representation

As a first step towards Digital Rights Management, in our concept we transform geodata into presentation objects. Hence geodata can only be accessed and used by the software interface defined in the corresponding geo-document classes. In object-orientation, this feature is known as *encapsulation* and leads to more stable, more reusable software designs.

The classes also define persistency functionality used to store and retrieve 3D geo-documents. In our concept, we use two serialization strategies: one based on binary serialization, the other based on an XML description. The first is used for the distribution of geo-documents, the latter is used to transparently store 3D geo-documents. The XML-based persistency relies on GML and provides a mapping between the internal object structure of a geo-document and the corresponding document object model (DOM) based on an XML schema. The authoring system is using this type of persistency to manage storage and retrieval of geo-documents. At this level, we do not provide Digital Rights Management (except that digital rights objects are stored like any other geo-document object).

The binary serialization allows us to store a whole geo-document as a "black box". To store a geo-document, all contained objects and their network, including data and object associations, are transformed into a single byte stream preserving all relationships and object states. For this, we traverse the geo-document and visit each geo-document object. Each object decides what attribute is considered persistent and writes its data into the binary data stream. To read a geo-document from a binary data stream, we create the initial geo-document object, the container, and reconstruct each serialized object.

Geo-documents as binary data streams are self-contained documents, that is, all required geodata (mostly transformed into graphics representations) are contained in the data stream. This compact representation simplifies the distribution. In addition, it would be impossible to precisely extract the original geodata from a binary data stream because geodata is contained in a transformed way. The binary serialization implicates a weak type of encryption because its encoding is exclusively defined by internal object structures. To further improve security, we can also encrypt the binary data stream on the fly. Note that encryption/decryption, however, are primarily means to guarantee a secure transfer of geo-documents between authors and users.

4 Representing Digital Rights

The term 'digital rights' and related management systems are defined in the scope of information technology as follows: „Digital Rights Management (DRM) systems restrict the use of digital files in order to protect the interests of copyright holders. DRM technologies can control file access (number of views, length of views), altering, sharing, copying, printing, and saving. These technologies may be contained within the operating system, program software, or in the actual hardware of a device." (EPIC, 2004) This definition also applies to digital rights in geo-documents, whereby we want to control object access instead of file access since we are operating on serialized object networks.

In geo-documents digital rights can be embedded in two ways: digital rights represented by specialized geo-document classes and digital rights implicitly defined by object permissions. Examples of DRM classes include:

- *Viewer Configuration*. The configuration defines what user interface elements are available in a distributed geo-document. Since most operations that can be applied to and used for geo-documents are represented in the general user interface system, the viewer configuration allows authors to exactly set up the functionality of a distributed geo-document;
- *Watermarks*. They represent graphical objects positioned in the view plane that cannot be removed. Watermarks can be integrated in a visible form or in an almost invisible form. Even if only part of an image is available, the existence of a watermark can be checked;
- *Camera Distance Restrictions*. The camera distance denotes the distance between center of projection and a georeferenced point. As 2D raster data, we can define the minimal camera distance. That is, for each geo position, we can set up a minimal "flight height", for example, to guarantee that a user does not approach an area where no appropriate data quality is available;
- *Camera Orientation Restrictions*. These restrictions limit all degrees of freedom of a virtual camera with respect to the terrain surface. For example, as a restriction we can prevent users from looking towards the sky, that is, users are enforced to see always at least part of the virtual terrain. This way, we can improve the usability of the navigation tools;
- *Collision Detection.* The collision detection applies to all geometric objects as well to invisible auxiliary objects that restrict the area a user can walk or fly in the virtual environment.

Examples of object permissions that define usage rights and constraints include:

- Permission to explicitly save a geo-document object. For example, a user may want to save a given 2D raster data set represented as terrain texture;
- Permission to include new geodata as presentation objects. For example, a user may want to extend a given geo-document by additional terrain information layers and, therefore, wants to include a new terrain texture;
- Permission to enable and disable contained presentation, structure, interaction, and animation objects. For example, a user may want to switch off a given terrain texture or to hide annotations.
- Permission to add and remove objects of specific presentation, interaction, and animation classes. For example, a user may be allowed to add label objects to personalize a geo-document, but may not be allowed to add new terrain textures;
- Permission to edit geo-documents by the authoring system. If a geo-document is distributed, this core permission determines, whether a user has the same rights as the author. If a geo-document cannot be edited by the authoring system, the usage rights and constraints apply and cannot be bypassed.

The maximal protection applicable to a geo-document consists in eliminating the viewer's user interface, protecting all contained objects together with disabling all navigation techniques so that users can only get a static image of the geovirtual environment. The minimal protection a geo-document allows all users to completely edit the whole document, that is, to freely insert and remove objects.

To illustrate further the scope for design, we outline a few possible types of distributed geo-documents:

- Distribution of geo-documents with a single navigation control that allows users to zoom in, to zoom out, and to move around a fixed geo-referenced position such as the center of interest;
- Distribution of geo-documents with view-plane buttons representing application-specific functionality. Examples include a view-reset button, a button to switch between two or more navigation controls, buttons to enable and disable (that is, show and hide) thematic layers, etc.;
- Distribution of geo-documents with built-in analysis tools, for instance, to interactively measure polylines and polygonal areas or to report terrain height or thematic values;
- Distribution of geo-documents that allow users to mark 3D positions by 3D labels and path objects and to store them as personal data inside the geo-document;
- Distribution of geo-documents that allow users to record own fly-through frame sequences.

The Digital Rights Managements objects together with the encoding of geo-documents in an object-oriented, serialized way leads to a well-designed DRM system. According to Koenen et al. (2004) such a system should provide three characteristics:

- *Governance.* DRM is based on executing DRM methods at runtime each time a geo-document is used. The run-time control goes beyond DRM techniques such as conditional access techniques for classical media. Technically, DRM is a fundamental part of the geovisualization system, modeled by specialized building blocks for geo-documents;
- *Secure association of usage rules with information.* We associate usage rules by adding DRM objects to a geo-documents and by setting up DRM permissions for each geo-document object and class. Once serialized, these usage rules cannot be removed unless the author explicitly allows users to change these associations;
- *Persistent protection throughout the content's commercial lifecycle.* The built-in DRM features of geo-documents cannot be changed due to serialization, so that they are kept throughout the lifecycle of a geo-document.

5 Applications of DRM in Geo-Documents

Embedded digital rights in geovisualizations based on the presented geo-document concept allows us to manage copyright, security, and privacy issues in geovirtual environments. Thereby, they also support the implementation of business models and lead to manifold product types and application scenarios.

5.1 Improving Usability of Geovirtual Environments

Geo-documents can be used to systematically build interactive geovirtual environments and provide manifold visualization techniques available through the various presentation, interaction, and animation classes. Above all, geodata can be interactively explored and analyzed. Integration at visualization level also allows for combining geodata of different formats within the same virtual environment – an interesting level for interoperability since many technical issues are bypassed compared to the integration at the data modeling level. They allow application developers to integrate geovisualizations in their own software systems as a reusable subsystem (Fig. 3).

Embedding digital rights in geovisualizations can improve usability of geovirtual environments by restricting and enforcing specific user interactions. For this purpose, developers use the application-programming interface (API) of geo-documents to create and manipulate geo-document objects including DRM objects. The application can construct and manipulate geo-document objects, and it can perform their operations while using the visualization subsystem for interactive display. Geo-documents in this scenario are used as high-level software components providing geovirtual environments. In our experience, the implementation of digital rights classes implies significant development efforts because they have an impact on the implementation of almost all presentation, interaction, and animation classes.

We have integrated successfully the LandXplorer system (3D Geo, 2004), an implementation of the geo-document concepts, as a subsystem into the planning system for radio networks of the German T-Mobile Company. Geo-documents are used to represent geodata of complex radio networks including 3D city models, radio network parameters can be explored and analyzed, and geoinformation can be distributed in form of geo-documents.

5.2 Publisher-Subscriber Geo-Documents

The publisher-subscriber paradigm can be implemented for geodata using geo-documents in a straightforward manner (Fig. 4). The publisher (or author) defines the contained geodata and the forms of their presentation, interactivity, and animation, and finally sets up usage rights and constraints. Once finished, the geo-document is serialized. In this form, it can be distributed by any digital media such DVD or Internet. Subscribers (or users) can activate the black-box geo-document by the built-in viewer application, so that the geo-document becomes a stand-alone application. The viewer application takes care of guarding digital rights.

Fig. 5 shows an example of a 3D route planning application based on high-resolution 3D geodata. Users can select the information layers interactively and get information about biking and hiking trails. The authors provide a customized viewer application and basically hide all geo-document objects except those relevant to the user.

5.3 Geo-Documents for Geodata Trading

For geodata warehouse applications (Fig. 6), geo-documents serve as containers of 3D geodata requested by customers. Based on an XML description, a server process is assembling geo-documents on demand; as output it is delivering the self-contained, serialized geo-documents. Note that customers don't get "the geodata" – they get an interactive application that is visualizing the geodata. The geodata vendor can implement different business models and offer varying degrees of access to the geodata based on the assigned usage rights and constraints.

6 Conclusions

The concept of geo-documents is based on a fine-grained object-oriented and graphics-oriented representation of presentation, interaction, animation, structure, and DRM classes. Hence, it offers a generic solution for embedding digital rights into geovisualizations. The concept is targeted towards software products that need to integrate geodata as core elements. Its strengths include the ability to integrate arbitrary geodata under a uniform paradigm, the geovirtual environments, and the ability to cope with privacy, security, and copyright issues. It also offers authors of geo-documents manifold possibilities to design geo-based software products and user interfaces.

In future work, we will address developing a broader range of geo-specific constraint objects and the aspect of collaborative visualization. Currently we are developing an extension that allows users of related geo-documents to communicate with each other across a network and to synchronize specific user activities. We will also address non-trivial operational models in the DRM context such as modifying and assembling digital rights and negotiating conflicts involving rules.

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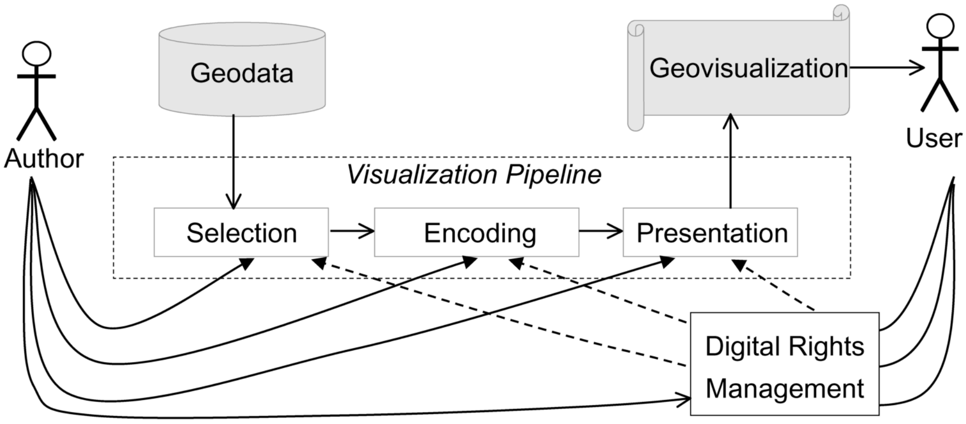

Fig. 1: The visualization pipeline and its principle processing stages in the context of geovisualization. Digital rights enable authors to control the way users can deploy, configure, extend, and redistribute geovisualizations.

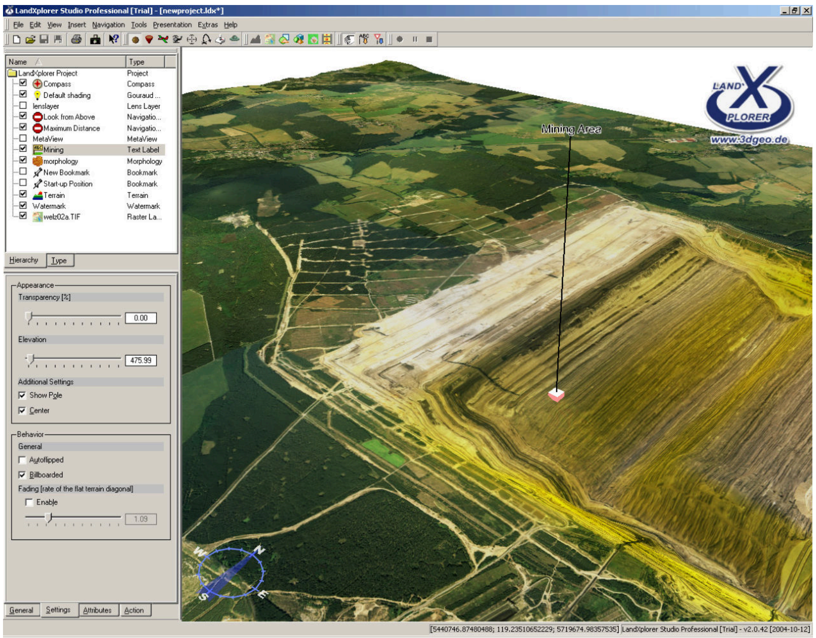

Fig. 2: User interface of LandXplorer authoring system for geo-documents. The tree on the left represents geo-document objects; the main widget displays a 3D map with a number of 2D and 3D geodata sets. (Image: www.3dgeo.de).

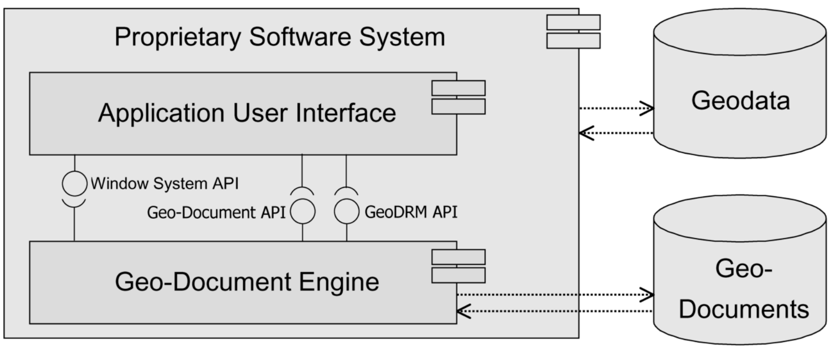

Fig. 3: Principle architecture of proprietary software systems that incorporate geovisualizations based on geo-documents. As subsystem the geo-document engine creates and manages geo-documents; it is integrated as part of the application's user interface and provides two APIs, one for presentation, structure, interaction, and animation geo-document classes and one for digital rights classes, called GeoDRM API.

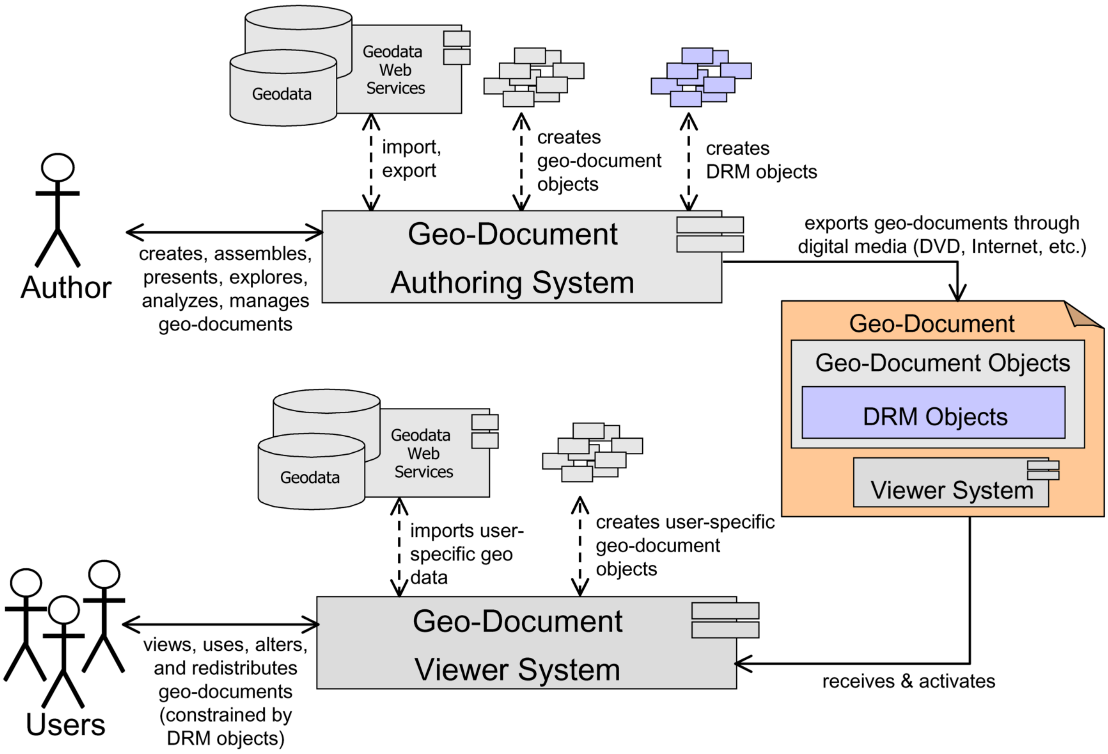

Fig. 4: Main use case of digital rights embedded in geovisualizations. Authors create geo-documents with appropriate digital rights. The resulting artifacts are delivered including the viewer systems, which is specified by digital rights as well. Usage of geo-documents is controlled by the embedded digital rights. Digital rights may allow users to personalize and to redistribute the received geo-documents.

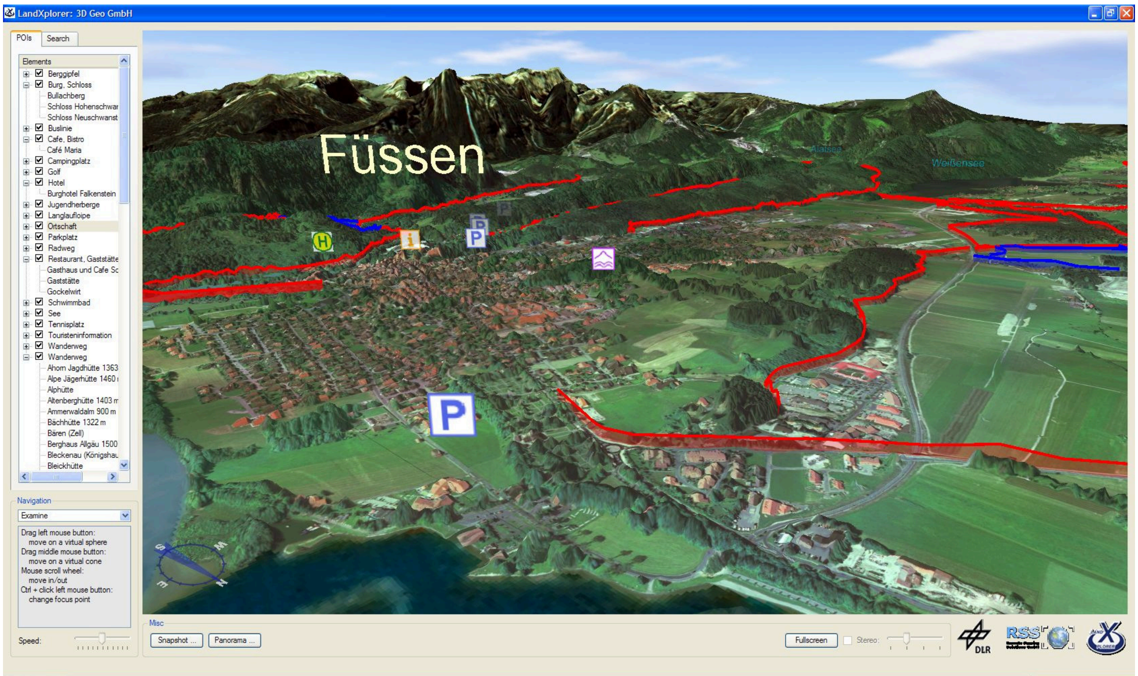

Fig. 5: An example for a consumer geo-document application: A tourist 3D information system used to display and to plan hiking trails. Embedded digital rights of the DVD product ensure that contained geodata such as aerial photography cannot be extracted. In addition, constraints are applied that restrict camera orientation, camera distance, and navigation modes.

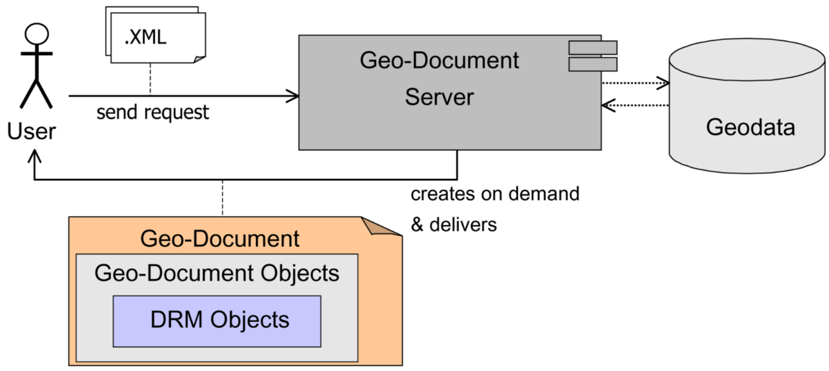

Fig. 6: Geo-documents used within a geodata trading application. A server process creates geo-documents. It creates and assembles geo-document objects based on an XML specification of the contents, and it inserts digital rights objects according to the business model underlying the individual user contract and request.